Express Mail No. EV 309292750 US
Attorney Docket: HON 1448-015F

Date of Deposit: September 29, 2003

ADHESION PROMOTER APPLICATION SYSTEM AND PROCESS

Inventors: Shubho Bhattacharya, Saul Gonzalez Gutierrez,
Laura McBride, Shojiro Takeuchi, and Yoshihiro Yamamoto

Cross-Reference to Related Applications

This application is a divisional of application Serial No. 09/577,776, filed May 24, 2000, for Adhesion Promoter Application System and Process, which is expressly incorporated herein by reference.

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] Environmental concerns have led to an attempted reduction of pollutants from a multitude of sources. Manufacturing facilities, have been required to operate under increasingly stringent emissions guidelines. These emissions guidelines require, in part, a reduction of volatile organic compound (VOC) emissions.

[0002] In a manufacturing environment, VOC's have a wide variety of uses. For example, certain VOC's have been commonly employed for the purpose of cleaning and preparing various plastic components for receiving a material coating, such as paint. More specifically, such VOC's are particularly useful for cleaning and preparing thermoplastic polyolefin (TPO) components for coating with a primer or paint product. Not only are such VOC's effective for the removal of grease and other contaminants which may reside on these components, they also act on the surface of the TPO to promote adhesion with the forthcoming primer or paint coating.

[0003] In an attempt to reduce emissions, it has become essential to drastically reduce or eliminate the use of VOC's. For similar reasons, most automobile

manufacturers also now employ a water-based paint and/or primer rather than traditional solvent-based products.

[0004] New plastic formulations have been developed which may be cleaned via non-VOC methods, and which are better able to bond with water-based paint and/or primer. However, TPO exhibits inherently poor wettability - meaning that it tends to repel moisture. Without the use of trichloroethylene or similar materials to prepare the surface, providing adequate paint adhesion is of great concern. For this reason, manufacturers utilizing a water-based cleaning system and water-based paint, typically provide the TPO components with a primer coat prior to the final paint or color coat.

[0005] Unfortunately, primer coating is a costly process. One reason is that a large portion of the sprayed primer is typically lost rather than deposited on the component. Additionally, once the components have received a primer coat, it is generally necessary to cycle them through an oven to allow the primer to fully dry. Therefore, it is desirous to develop a system and method that will allow a paint coating to be applied directly to the surface of a TPO component, without the need to first apply a coat of primer.

[0006] The present invention satisfies this need. The system and method of the present invention applies a water-based adhesion promoter to each TPO component. The adhesion promoter application preferably occurs after the component has undergone a cleaning process. After the adhesion promoter is applied and dried, a thin layer will remain on the surface of the TPO component. This thin layer of adhesion

promoter is sufficient to provide the necessary adhesion between the component and the forthcoming paint coat.

[0007] The adhesion promoter application system of the present invention may monitor a variety of parameters during operation, including, for example: line speed of the component; temperature of the component; temperature of the adhesion promoter; adhesion promoter nozzle distance and angle; adhesion promoter flow rate; nozzle spray pattern; setting zone time, temperature and relative humidity; and pre-oven and oven time, temperature and relative humidity. The adhesion promoter application system of the present invention may also be adapted to distinguish when a part is present within the system and to provide periodic water flushing in order to prevent adhesion promoter build-up.

[0008] Therefore, the adhesion promoter application system of the present invention allows a paint coat to be applied to the surface of a TPO component without the need to first apply a primer coat. As such, the present invention may provide a reduction in material, equipment and labor costs, as well as an increase in production capacity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In addition to the novel features and advantages mentioned above, other objects and advantages of the present invention will be readily apparent from the following descriptions of the drawings and embodiments, wherein:

Figure 1 is a schematic diagram illustrating various components comprising one embodiment of the system of the present invention;

Figure 2 is a pictorial diagram depicting a typical prior art TPO component coating system;

Figure 3 is a pictorial diagram depicting an embodiment of the TPO component coating process disclosed by the present invention;

Figure 4 graphically illustrates the stages of one embodiment of the adhesion promoter application process of the present invention;

Figure 5 is an enlarged front view, showing a series of TPO components passing through an application portion of one embodiment of the adhesion promoter application system of the present invention;

Figure 6 is an enlarged side view, in partial cross-section, depicting several components of the application portion of the embodiment of the adhesion promoter application system shown in Figure 5;

Figure 7 illustrates alternate embodiments of adhesion promoter application nozzles utilized in the present invention; and

Figure 8 is a schematic diagram detailing the operating procedure of a particular embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENT(S)

[0010] A schematic representation of various components of one embodiment of the adhesion promoter application system **10** of the present invention can be seen in Figure 1. A treatment enclosure **15**, which may be a portion of a larger pretreatment

enclosure, provides a captive environment for the application of the adhesion promoter to particular thermoplastic polyolefin (TPO) elements (not shown).

[0011] The treatment enclosure **15** is preferably closed at its entrance by a first air seal **20**, and at its exit by a second air seal **25**. A fan **30** may provide the air supply necessary to maintain the air seals **20**, **25**. The TPO elements are preferably cooled prior to entering the treatment enclosure **15,** thus, the first air seal **20** helps to prevent cool air from entering the treatment enclosure. A pre-oven is preferably connected to the exit portion of the treatment enclosure **15**. Similar in function to the first air seal **20**, the second air seal **25** helps to prevent hot air from the pre-oven from entering the treatment enclosure **15**. An air temperature and humidity conditioner **35** is preferably provided to maintain the atmospheric conditions within the treatment enclosure **15**. A chiller **40** and a boiler **45** are provided to supply cooled and heated water, respectively, to the air temperature and humidity conditioner **35**.

[0012] A supply tank **50** is preferably utilized to maintain a source of an adhesion promoter for use by the system **10**. A stock of adhesion promoter **55** and a supply of de-ionized water **60** are preferably in metered communication with the supply tank **50**. The adhesion promoter stock **55** is further metered and controlled by a surface tension meter **65**. The surface tension meter **65** is adapted to analyze a wet sample of adhesion promoter, and thereby control the amount of adhesion promoter and solvent that is supplied to the supply tank **50**. A re-circulation pump **70** is preferably used to re-circulate the adhesion promoter through an ultra-filtration module **75** for removing particulate contamination.

[0013] The adhesion promoter in the supply tank **50** is preferably supplied to a gravity tank **80** by means of a supply pump **85**. The adhesion promoter preferably passes through a supply filter **90**, and also passes through a heat exchanger **95** on its way to the gravity tank **80**. The heat exchanger **95** operates to adjust the temperature of the adhesion promoter traveling to the gravity tank **80**. Preferably, the temperature of the adhesion promoter in the gravity tank is maintained at between about 20-25°C. The chiller **40** and boiler **45** also supply cooled and heated water, respectively, to the heat exchanger **95**.

[0014] From the gravity tank **80**, the adhesion promoter is preferably directed to a multitude of nozzles **100** within the treatment enclosure **15** for application to the passing TPO elements. The temperature of the adhesion promoter may be monitored within the gravity tank **80** and the flow rate may be monitored at the nozzle **100** outlets to ensure proper application to the TPO elements. Operation and monitoring of the system **10** may be conducted via an operator/electrical panel **105**.

[0015] Alternate embodiments may also be possible. For example, the stock of adhesion promoter **55** and supply of de-ionized water **60** may be supplied directly to the gravity tank **80** or directly to the nozzles **100**. Alternatively, the supply tank **50** may be used without the gravity tank **80**, whereby the adhesion promoter may be supplied directly from the supply tank to the nozzles **100**.

[0016] Figure 2 illustrates a known TPO element coating process **120**. TPO elements traveling in a direction indicated by the arrows first enter a pretreatment enclosure **125**. Within the pretreatment enclosure **125**, the elements are subjected to a

washing/degreasing process, and typically, to a surface conditioning operation. Upon exiting the pretreatment enclosure **125**, the TPO elements enter a primer booth **130**, where a coat of primer is applied to promote adhesion between the TPO element and a later applied base coat. The primed TPO elements are then passed through a primer oven **135** in order to fully dry the primer coat. After the primer coat is fully dried in the primer oven **135**, the TPO elements enter a paint booth **140**, where they receive a base (color) coat and possibly a clear coat. The base coat, and if applicable the clear coat, are then dried in a paint oven **145** prior to their availability for final use.

[0017] An overview of the TPO element coating process **150** of the present invention can be seen by reference to Figure 3. In the present invention the TPO elements, traveling in the direction of the arrows, enter a pretreatment enclosure **155**. Within the pretreatment enclosure **155**, the TPO elements preferably undergo a washing/degreasing process and are then subjected to application of the adhesion promoter in a treatment section of the enclosure. Because the adhesion promoter allows a base coat to be applied directly to the adhesion promoter-treated surface of the TPO elements, the need for a primer booth and primer oven is obviated. Therefore, as shown in Figure 3, upon exiting the pretreatment enclosure **155**, the TPO elements may enter directly into a paint booth **160**, where they receive a base (color) coat and possibly a clear coat. The base coat, and if applicable the clear coat, are then dried in a paint oven **165** prior to their availability for final use.

[0018] Another advantage to the process of the present invention is depicted in Figure 3. Because no primer booth or primer oven is required, at least one additional paint

booth **170** and paint oven **175** may be available for receiving adhesion promoter-treated parts. The additional paint booth **170** and paint oven **175** may be created by converting a pre-existing primer booth and primer oven, for example. Thus, the adhesion promoter application system and process of the present invention may also serve to double the production capacity of the TPO element paint process.

[0019] A graphical representation of the various stages of an embodiment of the adhesion promoter application process **200** of the present invention can be seen in Figure 4. For purposes of clarity, the enclosure portion of the system is represented as transparent. It should also be noted that although a carrier **225** is shown in Figure 4 to hold only one TPO element **210**, it is possible, and typically desirable that each carrier transport multiple elements.

[0020] The TPO element **210**, represented in this embodiment as an automobile bumper fascia, can be seen near a cooling portion **215** of a pretreatment enclosure **220**. As represented in this position, the TPO element **210** has already been subjected to a washing/degreasing operation in a more forward portion (not shown) of the pretreatment enclosure **220**.

[0021] Because the temperature of the TPO element **210** has likely become elevated during the washing/degreasing operation, the TPO element is transported in the direction of the arrows by the carrier **225**, and through a cooling device **230**. For purposes of illustration, the cooling device **230** may be a series of nozzles spraying cooled, de-ionized water, as represented here, but other embodiments are also possible that can produce the desired effect. The cooling device **230** preferably reduces the

temperature of the TPO element **210** to approximately that of the adhesion promoter application section **235** of the pretreatment enclosure **220**. Cooling of the TPO element **210** is desirable to prevent heat transfer from the TPO element to the atmosphere within the adhesion promoter application section **235** of the pretreatment enclosure **220**.

[0022] A first air seal **240**, preferably created by a fan **30** (Figure 1), assists in preventing the atmosphere of the cooling portion **215** of the pretreatment enclosure **220** from influencing the atmosphere within the adhesion promoter application section **235**. The temperature of the first air seal **240** is preferably maintained at approximately the desired interior temperature of the adhesion promoter application section **235** of the pretreatment enclosure **220**.

[0023] The TPO element **210** and carrier **225** pass through the first air seal **240** and into the adhesion promoter application section **235** of the pretreatment enclosure **220**. A second air seal **245** separates the adhesion promoter application section **235** of the pretreatment enclosure **220** from a pre-oven **265**. At a point preferably nearer the first air seal **240**, an application portion **250** (Figures 5-7) of the adhesion promoter application system applies the adhesion promoter **255** to the TPO element **210**. The linear velocity of the carrier **225** and TPO element **210** during application of the adhesion promoter is preferably between approximately 1-5 meters per minute, and in one example embodiment, is approximately 1.2 meters per minute.

[0024] The remaining segment of the adhesion promoter application section **235** of the pretreatment enclosure **220** located between the application portion **250** and the second air seal **245** is used as a setting zone **260**. The setting zone **260** allows at least

a portion of the adhesion promoter to flash off of the TPO element **210** before entering the pre-oven **265**. Preferably, the adhesion promoter application section **235** of the pretreatment enclosure **220** is maintained at a temperature of between about 20-25°C and a relative humidity of between approximately 40-70%.

[0025] Upon exiting the adhesion promoter application section **235** of the pretreatment enclosure **220** through the second air seal **245**, the TPO element **210** preferably enters a pre-oven **265**, where the temperature of the TPO element and the remaining adhesion promoter is elevated prior to entering a drying oven **270**. The temperature may vary from between approximately 25-65°C, and the relative humidity may vary from between about 15-60% depending on the location of the TPO element **210** within the pre-oven **265**.

[0026] The adhesion promoter remaining on the TPO element **210** is preferably further dried in the drying oven **270** prior to entering a paint booth **160**, **170** (Figure 3). The temperature may vary from between approximately 45-95°C, and the relative humidity may vary from between about 5-25% depending on the location of the TPO element **210** within the drying oven **270**.

[0027] An enlarged, frontal view of an embodiment of the application portion **300** of the adhesion promoter application system is shown in Figure 5. Multiple TPO elements **210** can be seen to be placed in communication with a supply of an emitted adhesion promoter **310** by the carrier **225**. In this embodiment, the adhesion promoter **310** is supplied, preferably via a gravity tank (not shown), to a main and secondary supply header **315**, **320**. The use of a gravity tank helps to prevent foaming of the adhesion

promoter **310** as it contacts the TPO elements **210**, by reducing the amount of air trapped therein. It has been found that excessive foaming may lead to defects, such as streaks, runs, and sags in the layer of adhesion promoter deposited on the TPO elements **210**.

[0028] Each of the main and secondary supply headers **315**, **320** are shown to have multiple nozzles **325**, **330** for distributing the adhesion promoter **310** upon the TPO elements **210** passing underneath. Although the number of nozzles **325**, **330** may vary, good results have been achieved by using between about 15-30 total nozzles.

[0029] The nozzles may be of differing configuration to allow for various adhesion promoter **310** distribution patterns. Various shapes, such as a stream **335** or a fan pattern **340**, for example, may be employed to most appropriately distribute the adhesion promoter **310** about the TPO components **210** without causing defects.

[0030] Each of the nozzles **325**, **330** preferably also possesses its own flow control device (not shown). The flow control device may be a manual valve, or an electronic solenoid operated valve, for example. The use of a flow control device is preferred, as it has been found that the flow rate of the adhesion promoter **310** can affect the quality of the final adhesion promoter layer that will remain on each of the TPO components **210**. Satisfactory results have been achieved using an adhesion promoter flow rate of between approximately 0.5-2.5 liters per minute, and in one example embodiment, the adhesion promoter flow rate is approximately 1.5 liters per minute.

[0031] Figure 6 is an enlarged side view, in partial cross-section, which illustrates the supply headers **315**, **320** and nozzles **325**, **330** of Figure 5 in more detail. A cross-

section of typical header **315**, **320** construction is shown to be partially filled with the adhesion promoter **310**. The headers **315**, **320** may be manufactured of various materials, such as, for example, PVC pipe. The nozzles **325**, **330** extend from the headers **315**, **320** and are in communication with the adhesion promoter **310** located therein. The nozzles **325**, **330** may be constructed of various types and sizes of pipe or tubing, and are preferably manufactured of a plastic or stainless steel material. As discussed above, it is also preferable that the nozzles **325**, **330** possess some type of flow control (not shown).

[0032] As can be seen, the nozzles **325**, **330** are preferably angled in the direction of travel of the TPO elements **210**, which direction is indicated by the arrow. Delivering the adhesion promoter **310** through an angled nozzle **325**, **330** appears to reduce the force of impact on the TPO element **210** by the adhesion promoter, thereby reducing foaming and subsequent adhesion promoter layer defects. Although the optimum angle **ø** of the nozzles may vary depending on the configuration of the TPO element **210** to which the adhesion promoter **310** is to be applied, good results have been obtained utilizing a nozzle angle **ø** of between about 10-45 degrees relative to vertical. However, based upon factors such as TPO element configuration, TPO element linear velocity, adhesion promoter flow rate, and nozzle to element distance, for example, lesser or greater nozzle angles may also give satisfactory results.

[0033] As also shown in Figure 6, it may be preferable to position the TPO element **210** at an angle **ß** as it passes beneath the adhesion promoter **310**. In the embodiment of Figure 6, the TPO element **210** is shown to be angled on the carrier **225**, toward its

direction of travel and away from the nozzles **325**, **330**. It has been found that orienting the TPO element **210** as shown may reduce the amount or severity of defects appearing in the adhesion promoter layer that remains on the TPO element after drying. As with the nozzle angle ø discussed above, the optimum angle ß of TPO element **210** orientation on the carrier **225** will depend largely on the configuration of the TPO element and other application parameters. However, good results have been achieved for the embodiment illustrated in Figure 6 by orienting the TPO element **210** on the carrier **225** at an angle ß of between about 5-20 degrees, and more preferably about 12 degrees from vertical, in a direction away from the nozzles **325**, **330**.

[0034] Now referring to Figure 7, a frontal, detailed view of the nozzles **325**, **330** of Figures 5 and 6 can be seen. Three different types of nozzles **325**, **330** are shown to extend from the supply header **315**, **320**. A single stream nozzle **350** is shown on the right. The single stream nozzle **350** is adapted to deliver an adhesion promoter stream **355** of substantially uniform diameter to the TPO element **210**. A dispersion nozzle **360** can be seen in the middle position. The dispersion nozzle **360** is designed to apply a wider pattern **365** of the adhesion promoter to the TPO element **210**. A fan nozzle **370** can be seen on the left. The fan nozzle **370** preferably has a thin opening **380** of between approximately 20-30 millimeters in width, which causes the adhesion promoter **310** to exit the nozzle in substantially a fan pattern **375**. Depending on the distance between the nozzles **325**, **330** and the TPO element **210**, the length **L** of the fan portion **375** of the adhesion promoter stream **385** is preferably between about 10-150 millimeters.

[0035] A variety of nozzle diameters **390** may be employed to adequately expel the adhesion promoter **310**. However, for the embodiments illustrated in Figures 5-7, the best results have been achieved by using a nozzle diameter of between approximately 0.25-0.50 inches, with a nozzle opening diameter **395** of between about 0.5-1.0 millimeters.

[0036] It has been discovered through experimentation that the distance **D** between the nozzles **325**, **330** and the surface of the TPO element **210** also may have bearing on the quality of the adhesion promoter layer that will be deposited thereon. As with flow rate and angle of impact, it appears that the distance **D** between the nozzles **325**, **330** and the surface of the TPO element **210** affects the amount of splashing and foaming of the adhesion promoter **310** that will occur. Depending on adhesion promoter flow rate, linear speed of the TPO elements **210**, and TPO element configuration, a distance **D** of between approximately 0.25-14 inches has yielded acceptable results. For the embodiments shown in Figures 5-7, however, a distance **D** of approximately 1.75 inches is preferable. Due to variations in distance **D** that may be required between different TPO elements, it is preferable that a part collision detection limit switch means be employed to ensure that a TPO element is not able to collide with any of the nozzles **325**, **330**.

[0037] The operating procedure of a particular embodiment of the present invention can be seen in the diagram of Figure 8. A master on switch **410**, which delivers electrical power to the system, is first activated. Electrical power is then in turn applied, either by manual activation or automatically, to: the TPO element conveyor **415**, which

is constrained via an interlock to check the condition of one or more part collision detection limit switches **420**; the air seal fan **425**; and the air conditioning (atmosphere control) fan **430**. Upon activation of the air conditioning fan **430**, a signal is sent from both an enclosure temperature sensor **435** and an enclosure humidity sensor **440**. The enclosure temperature sensor **435** and enclosure humidity sensor **440** are in respective communication with a modulating valve for the hot water return from the air-conditioning coil **445** and a modulating valve for the chilled water return from the air-conditioning coil **450**. This allows for automatic control of the temperature and relative humidity within the enclosure **15**. A check is then made to verify that both the chiller and boiler are operational **455**.

[0038] Next, electrical power is applied to a pump for supplying the adhesion promoter **460**. Upon activation of the adhesion promoter pump **460**, an adhesion promoter tank temperature sensor **465**, which is in communication with both a modulating valve for the hot water return from the heat exchanger **470** and a modulating valve for the chilled water return from the heat exchanger **475**, operates to maintain the desired temperature of the adhesion promoter. Activation of the adhesion promoter pump **460** also triggers a check of adhesion promoter on/off flow control valves **480**, and part-gap detection photo sensors **485**, which evaluate the position of the adhesion promoter application nozzles in relation to the TPO elements to be treated. The adhesion promoter on/off flow control valves **480** are also interconnected to a solenoid valve for de-ionized water nozzle purging **490**, which periodically provides de-ionized water to the nozzles to prevent the build-up of adhesion promoter.

[0039] A filtration pump **495** and a de-ionized water pump **500** are then turned on. The energizing of the de-ionized water pump **500** activates a de-ionized water temperature sensor **505**. The de-ionized water temperature sensor **505** is in communication with the modulating valve for the chilled water return from the heat exchanger **510**, which allows the temperature sensor **505** to control the temperature of the de-ionized water supply that may be used, among other things, to rinse and cool the TPO elements prior to application of the adhesion promoter.

[0040] An adhesion promoter tank pH sensor is next activated **515**, along with an adhesion promoter tank electrical conductivity sensor **520**. The pH sensor **515** and the conductivity sensor **520** allow the properties of the adhesion promoter to be monitored.

[0041] The scope of the invention is not to be considered limited by the above disclosure, and modifications are possible without departing from the spirit of the invention as evidenced by the following claims: